CEMENT

AND

CEMENT MANUFACTURE

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The New Italian Cement Specification.

A NEW specification for cement issued by the Italian Government came into effect on January 1, 1934. The following materials are covered: Hydraulic lime; strongly hydraulic lime; Portland cement; aluminous cement; blast-furnace cement; pozzolana cement; quick-setting cementitious materials; slow-setting cementitious materials.

Definitions.

Limes are to be made from natural marl or homogeneous mixtures of limestone and argillaceous material. Portland cement is defined in the usual way. Aluminous cement must contain at least 35 per cent. Al_2O_3. Blast-furnace cement is to be made from plain cement clinker and basic blast-furnace slag suitably granulated, and must not contain more than 5 per cent. manganous oxide (MnO). The clinker may be prepared from limestone and blast-furnace slag. Pozzolana cement is to consist of a homogeneous mixture of plain cement clinker and pozzolana. The clinker may be made from limestone and pozzolana. No inert material may be added after burning to Portland, aluminous, blast-furnace and pozzolana cements.

If standard specimens of these cements reach a compressive strength of 600 kg. per sq. cm. (8,550 lb. per sq. in.) after 28 days' storage, they may be called "high-strength" cements. "Cementitious materials" may be any of the cements possessing a lower strength than the above or containing inert admixtures.

In all these materials, both limes and cements, the magnesia must not exceed 3 per cent., or the sulphuric anhydride 2 per cent.

Methods of Testing.

Fineness is tested by two sieves mechanically shaken, one with 900 meshes per sq. cm. (76×76 sieve), the other with 4,900 meshes per sq. cm. (180×180

sieve, approximately, or B.S. sieve 170 × 170). The specific gravity test is carried out in the usual way with material passing the 900-mesh sieve.

Normal consistency is determined with a flat-ended rod of 1 cm. diameter and 300 gm. weight, which must penetrate only to 6 mm. from the base of the mould. The cement paste is prepared by gauging 1 kg. of cement with water low in chlorides and sulphates. The mould is to be a metal or ebonite truncated cone 4 cm. high, 9 cm. diameter at the bottom, and 8 cm. at the top.

The Vicat needle test is used for determining the initial and final set and the test is carried out on paste of normal consistency.

The standard sand used for mortar specimens must be retained between sieves with 1.0 and 1.5 mm. diameter holes and made of perforated metal. Standard mortar is prepared from one part by weight of cementing material and three parts by weight of standard sand. The materials are first mixed dry by hand for one minute, water is added, and the whole mixed for a further minute. The mixture is then placed in a machine mixer consisting of a rotating basin and roller; the basin is to make 20 revolutions in 2½ minutes. The amount of gauging water is to be fixed by the manufacturer, or failing this by the testing laboratory. In these tests the temperature must not exceed the limits of 15 to 20 deg. C. for the normal consistency and setting time tests and 15 to 25 deg. for the mortar tests.

Slow-setting cements and cementitious materials are to be tested in the form of standard briquettes of the usual minimum cross section of 5 sq. cm. The moulds are to receive 120 blows from a hammer weighing 2 kg. dropping through a height of 0.25 metre. After 24 hours in a damp atmosphere of at least 80 per cent. humidity for cements and 48 hours for the hydraulic limes, the specimens are to be immersed in fresh water at 15 to 20 deg. C., which must be changed every 7 days.

The tensile strength specimens must be tested immediately after removing from the water at the following ages: Hydraulic limes, after 28, 84, 180, and 360 days; Portland cement, blast-furnace cement, pozzolana cement, and cementitious materials, after 7, 28, 84, 180, and 360 days; high-strength cements, after 3, 7, 28, 84, 180, and 360 days; aluminous cement, after 24 hours, 3, 28, 84, 180, and 360 days. Six specimens are to be tested and the mean of the four best figures taken as the tensile strength.

Quick-setting cements are filled into the moulds with the spatula only, and after 30 minutes they are placed in a damp atmosphere. The tensile tests are made after 1, 3, 7, 28, etc., days as before.

The compression specimens are to be made of 3 : 1 mortar in cubical moulds of 50 sq. cm. cross section. They are to receive 160 blows from a hammer of 3 kg. weight falling 0.50 metre. The loading is to be carried out at the rate of 20 kg. per sq. cm. per second. Quick-setting cements are not to be rammed with the hammer. The ages at which the specimens are to be tested are the same as for the tensile strength specimens.

Volume constancy is measured by the Le Chatelier method. Pats 10 to 15 cm. in diameter and 1.5 to 2 cm. thick tapered at the edge to 5 mm. may also be used for this test. In this case deformation or radial cracks are observed.

The cold soundness test is carried out in the same way except for the 3 hours boiling ; instead, the specimens are kept in water at 15 to 20 deg. C. and examined after 28 days.

Specimens for the bending test are to be 12 cm. long and 2 cm. square in section. These are tested by placing them on two slightly rounded knife edges 10 cm. apart. A side of the specimen in contact with the mould must be in contact with the knife edges during the test. The load is applied at the centre by means of a rounded knife edge and must be applied at the rate of 1 kg. per second. The ages for testing are the same as for the tensile and compression strength specimens, and the mean of the four best figures in each test is taken. The stress is to be calculated according to the equation

$$\sigma = \frac{My}{J} = \frac{15}{8} . P$$

where P is in kilograms.

In special cases the following tests can also be required: Shear strength, adhesion, permeability and porosity, resistance to sea water, and chemical analysis.

Methods of Testing.

The cements must be delivered in sacks of 50 kg. each, each sack being closed with a wire loop provided with a lead seal on which is marked the name of the maker and the type of cement. Labels must be provided on sacks of slow-setting cement and cementitious materials bearing the following information: Quality of cement, name of manufacturer, amount of water for mortar of normal consistency, guaranteed minimum tensile and compressive strengths at 28 days, and approximate amount of added inert materials in the case of cementitious materials. In the case of high-strength cements the label must also state the 3- and 7-day tensile and compressive tests, and for aluminous cements the 24-hour and 3-day tensile and compressive tests.

In no case may the strengths be lower than the following:

Portland, blast-furnace, and pozzolana cements: Tensile strength—25 kg. per sq. cm. at 7 days, 30 kg. per sq. cm. at 28 days. Compressive strength—350 kg. per sq. cm. at 7 days, 450 kg. per sq. cm. at 28 days.

High-strength Portland, blast-furnace, and pozzolana cements: Tensile strength—20 kg. per sq. cm. at 3 days, 30 kg. per sq. cm. at 7 days, 35 kg. per sq. cm. at 28 days. Compressive strength—250 kg. per sq. cm. at 3 days, 450 kg. per sq. cm. at 7 days, 600 kg. per sq. cm. at 28 days.

Aluminous cement: Tensile strength—25 kg. per sq. cm. at 24 hours, 30 kg. per sq. cm. at 3 days, 40 kg. per sq. cm. at 28 days. Compressive strength—300 kg. per sq. cm. at 24 hours, 500 kg. per sq. cm. at 3 days, 650 kg. per sq. cm. at 28 days.

Cementitious materials: Tensile strength—18 kg. per sq. cm. at 7 days, 22 kg. per sq. cm. at 28 days. Compressive strength—180 kg. per sq. cm. at 7 days, 300 kg. per sq. cm. at 28 days.

The mechanical and physical properties of the hydraulic limes must conform to the figures given in Table I. One out of every 1,000 sacks (in urgent cases, one in 2,000) must be tested.

TABLE I

Description.	Max. residue on sieve with		Min. sp. gr.	Setting time.		Minimum strength in kg. per sq. cm.							
						Tensile strength after				Compressive strength after			
	900 meshes per sq. cm. %	4,900 meshes per sq. cm. %		Initial hours.	Final hours.	24 hours.	3 days.	7 days.	28 days.	24 hours.	3 days.	7 days.	28 days.
Hydraulic lime...	7	25	2.70	2 to 6	8 to 48	—	—	—	5*	—	—	—	25*
Strongly hydraulic lime	7	25	2.70	2 to 6	8 to 48	—	—	—	8*	—	—	—	50*
Quick-setting cementitious materials ...	15	—	2.80	1/60	½	—	—	12†	—	—	—	120†	—
Slow-setting cementitious materials ...	2	20	2.80	1	6 to 12	—	—	18*	22*	—	—	180*	300*
Portland, blast-furnace and pozzolana cements ...	2	20	2.90	1	6 to 12	—	—	25*	30*	—	—	350*	450*
High-strength cements:													
Portland ...	2	15	3.05	1	6 to 10	—	20*	30*	35*	—	250*	450*	600*
Blast-furnace	2	15	2.90	1	6 to 10	—	20*	30*	35*	—	250*	450*	600*
Pozzolana ...	2	15	2.90	1	6 to 10	—	20*	30*	35*	—	250*	450*	600*
Aluminous ...	2	15	3.05	1	4 to 7	25*	30*	—	40*	300*	500*	—	650*

* With standard mortar. † With standard neat paste.

Portland, blast-furnace, and aluminous cements may not have a loss on ignition greater than 3 per cent. or an insoluble residue larger than 1½ per cent. Pozzolana cements may not contain more than 5 per cent. calcium carbonate.

Cement may be accepted provisionally on the 7-day tests. It must pass the hot and cold soundness tests, but in the case of disputes the hot soundness test is decisive.

Book Review.

"The Uses of Blast Furnace Slag," by Dr. A. Guttmann. Second Edition. (Dusseldorf: Verlag Stahleisen G.m.b.H.) Pp. 462 + XI. Price 16 Marks.

This book, written in the German language, deals with the chemistry and physics of blast furnace slag and its various uses in connection with the production of cement, concrete, bricks, material for railways and roads, light-weight aggregate, slag wool, etc. Methods of granulating and drying slag are described, but very little space is given to the use of slag either as a raw material for cement manufacture or as an addition to Portland cement. Slag as an ingredient of concrete both as slag-sand and crushed aggregate is dealt with in more detail. The book is well illustrated.

Heat Transmission in Rotary Kilns.—VIII.

By W. GILBERT, Wh.Sc., M.Inst.C.E.

The Combustion Zone of the 400-ft. Kiln.

(154) IT will be convenient at this stage to introduce a graph (Fig. 28) which shows the temperature distribution in the gas, the lining, the chains, and the material throughout the length of the kiln. The stage lengths on the diagram are arranged to suit the changes which take place in the material as described in para. (110). As shown by Fig. 19, the length of kiln available for heat transmission is 385 ft.

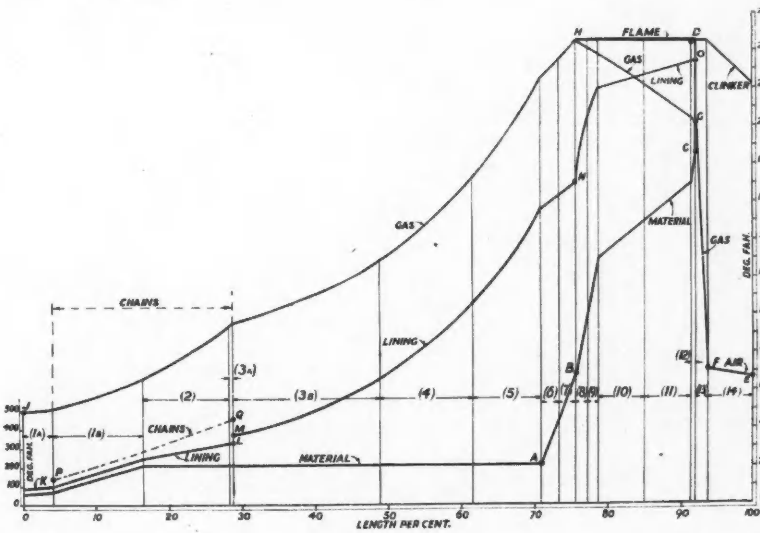

Fig. 28.

As calculated, stages (1) to (5) require 276.1 ft., stages (6) to (12) require 88.6 ft., and to this is added 5 ft. for stage (13) and 22 ft. for stage (14), the latter distance being measured on the site. Hence the total length, as estimated, becomes 391.7 ft., or 6.7 ft. too much. When drawing the base line of Fig. 28 the various stage lengths are shown as a percentage of 391.7 ft., so that the error is distributed throughout the length of the kiln.

(155) Taking first the material line, dry raw material is obtained at rather more than 70 per cent. of the kiln length (see point A), and the zone of gas radiation and convection ends at point B where the material temperature is 690 deg. F.

Heat is now supplied mainly by flame radiation, the $CaCO_3$ is decomposed, and the material is finally raised from 1,850 deg. F. at point *C* to 2,450 deg. F. at point *D* by the exothermic reaction. This operation is shown as a vertical

line on the diagram, but in practice it is of course spread over some length of the kiln. After clinker is made its temperature falls throughout stage (14) to 2,220 deg. F. at the kiln outlet.

Taking next the air and gas temperature line, air enters the kiln at point *E*, and after being heated 35 deg. F. by the outgoing clinker its temperature reaches 710 deg. F. at point *F*, where ignition takes place. The corresponding preheat, as shown by the cooler heat balance in para. (115), is 3.20 per cent.

The calorific value of the volatile matter was estimated to be 3,995 B.T.U. per pound of dry coal as fired, which by para. (113) is equivalent to 8.57 per cent. Its combustion is assumed to take place completely in stage (13), and as a result the mixed gas and air temperature rises to 2,012 deg. F. at point *G*. The combustion of the coke particles finally raises the gas temperature to 2,450 deg. F. at point *H*, where combustion is complete.

TABLE XXIII.

GAS COMPOSITION AND TEMPERATURE IN COMBUSTION ZONE.
(ALL QUANTITIES RELATE TO THE BEGINNING OF EACH STAGE).

			STAGE NUMBERS						
			(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	Weight of the products of combustion, and of excess air per pound of dry coal as fired, in lb.	CO_2	2·36	2·18	2·01	1·23	0·42	0·35	
2		H_2O	0·45	0·45	0·45	0·45	0·45	0·45	
3		N_2	6·67	6·25	5·84	3·94	1·98	1·80	
4		AIR	0·90	1·45	2·00	4·46	7·02	7·25	9·60
5	From the raw material lb.	CO_2	1·91	1·91	1·91	0·95	—	—	—
6	TOTAL		12·29	12·24	12·21	11·03	9·87	9·85	9·60
7	Heat supply to the gases, including preheat	per cent.	16·38	15·99	15·60	13·80	11·92	11·77	3·20
8	Gas temperature at begining of stage	deg. Fah	2450	2410	2369	2229	2036	2012	710

The method of obtaining the gas composition and temperature in the combustion zone of the 200-ft. kiln was outlined in paras. (91) and (92), and the corresponding figures for the 400-ft. kiln are set down in Table XXIII. The curve *FGH* on Fig. 28 was plotted from the figures in line (8). The remainder of the gas temperature curve (between *H* and *J*) is obtained from Tables XIX and XXI.

(156) The average lining temperature (for circle) throughout the kiln is shown by the curve *KLMNOD*. Where chains occur the lining temperature is reduced due to shielding ; hence the curve is discontinuous. It is plotted from figures given in Tables XXI and XXV.

The average chain temperature is shown by the line *PQ*, which is based on the figures given in line (4) of Table XXI. Since making the calculations now published for the 400-ft. kiln the chains have been carried for some distance farther down, and exit-gas temperatures of 400 deg. F. are reported. Allowing for pyrometer radiation loss the true exit-gas temperature is approximately 432 deg. F.

Dimensions and Data for Combustion Zone.

(157) Before proceeding to calculate the stage lengths in the combustion zone some further items required for that purpose are gathered together in Table XXIV. The figures in lines 2, 3 and 4 are derived mainly from Table XXIII. The convection constants are calculated by the aid of formula (5) and Table VI in Part II. The P.D. values for gas radiation have been calculated from the average gas composition in each stage when estimated by volume, and from the diameters given in line (1).

Calculation of Lengths of Stages (6) to (12).

(158) When calculating the stage lengths it is found convenient to take first stages (1) to (5) which make up the drying zone; this result is shown in Table XXI, where values of H_{con} are used. For dry material the method of calculation is somewhat different and it is preferable to tabulate stages (6) and (7), which are in the zone of gas radiation and convection, with stages (8) to (12) which form the combustion zone. This is done in Table XXV.

TABLE XXIV.

PRELIMINARY DATA FOR COMBUSTION ZONE.
(ALL QUANTITIES ARE AVERAGE VALUES FOR EACH STAGE.)

			STAGE NUMBERS				
			(8)	(9)	(10)	(11)	(12)
1	Kiln diameter inside lining	ft.	10·2	10·2	10·2	10·2	10·2
2	Gas per hour per square foot of cross section	lb.	1410	1405	1400	1267	1133
3	Gas volume per pound of coal at stage temperature	cu. ft.	821	809	786	696	628
4	Gas velocity	ft. per second	26·2	25·8	25·0	22·2	20·0
5	Convection Constant H_c (a) Gas and lining		1·25	1·21	1·19	1·10	1·01
6	Convection Constant H_c (b) Gas and material		1·43	1·36	1·30	1·18	1·08
7	Values of P.D (a) for H_2O		0·65	0·65	0·65	0·69	0·74
8	Values of P.D (b) for CO_2		2·53	2·43	2·32	1·38	0·28
9	Charge in kiln 6·0 per cent. upper lining arc 25·12 ft., lower arc 6·89 ft., chord 6·37 ft						

(159) Line (1).—The heat transmitted in stages (6) and (7) is obtained from Table XVIII, and in the remaining stages from para. (116). In stage (12) a small addition of 0.02 is made for shell radiation, leaving 0.10 for stage (13).

Line (2).—The radiation from the incandescent coke particles into stages (13) and (14), where the average temperature is 2,335 deg. F., is shown later to be 0.25 per cent. The total heat transmission by flame radiation in stages (8) to (12), as set down in lines (1) and (2), will be found to add up to 11.32 per cent. This compares with the figure given in para. (118*a*).

Line (3).—The flame temperature has been standardised at 2,450 deg. F.

Line (4).—The average gas temperature in stages (6) and (7) is taken from Table XVIII, and in stages (8) to (12) it is obtained from Table XXIII.

Lines (5), (7), and (10) will be explained later.

Line (8).—The average material temperature in each stage can be deduced by reference to Table XVIII and to para. (110).

TABLE XXV.

HEAT TRANSMISSION IN COMBUSTION ZONE AND IN STAGES (6) AND (7).

			RAISING DRY RAW MATERIAL TEMPERATURE				DECOMPOSITION OF C_ACO_3		RAISING TEMPERATURE
			(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	Heat transmitted to material, per cent on clinker		0·75	0·76	0·96	0·96	4·42	4·41	0·32
2	Heat radiated into stages (13) and (14)	do. do.	—	—	—	—	—	0·22	0·03
3	Flame temperature	deg. Fah.	—	—	2450	2450	2450	2450	2450
4	Average gas temperature	do.	2300	2400	2430	2389	2300	2133	2024
5	Average lining temperature, upper arc	do.	1635	1709	2028	2168	2282	2343	2368
6	do. do. circle	do.	1605	1677	1978	2113	2226	2293	2321
7	do. do. lower arc	do.	1496	1561	1800	1918	2023	2100	2152
8	Average material temperature	do.	331	570	842	1148	1400	1600	1775
9	Shell radiation factor		0·072	0·072	0·072	0·072	0·072	0·072	0·072
10	Storage factor for kiln lining		0·93	0·92	0·86	0·81	0·75	0·71	0·68
11	Density factor "F" for coke particles		—	—	0·22	0·41	0·67	0·87	0·93
12	Flame radiation to upper lining arc	All heat quantities in lines (12) to (24) are in B.T.U. per foot run of kiln per minute	—	—	4312	5762	5957	5088	4214
13	Gas radiation to do. do.		3151	3900	2415	1091	45	-209	-176
14	Gas convection to do. do.		404	397	210	112	9	- 97	-148
15	TOTAL, flame & gas to upper lining arc		3555	4297	6937	6965	6011	4782	3890
16	Flame radiation to material chord		—	—	2128	3750	5627	6560	6112
17	Gas radiation to do. do.		1265	1570	1448	965	413	99	25
18	Gas convection to do. do.		360	309	241	179	124	67	29
19	TOTAL, flame & gas to material chord		1625	1879	3817	4894	6164	6726	6166
20	Lining radiation to material chord		1674	2047	3103	2774	1707	661	324
21	Lining radiation to material arc		1536	1839	3118	3401	3493	3354	2896
22	Shell radiation loss		345	411	716	790	811	767	670
23	TOTAL, heat taken from lining		3555	4297	6937	6965	6011	4782	3890
24	TOTAL HEAT TRANSMITTED		5,180	6,176	10,754	11,859	12,175	11,508	10,056
25	Length in kiln required for stage	feet	10·5	9·0	6·5	5·9	26·5	27·9	2·3
26	Added length of stages from feed end of kiln	do.	286·6	295·6	302·1	308·0	334·5	362·4	364·7

Line (11).—The density factor for the coke particles is explained in paras. (31) to (36). Taking the middle point of stage (10), for instance, the percentage of the average coke particle not burned (denoted by b) is obtained from lines (1) and (2) of Table XXV, as follows :

$$b = \frac{11.32 - 7.17}{11.32} \times 100 = 36.5$$

A sedimentation test of the coal, which was ground to a residue of 35.5 per cent. on a sieve with 170 meshes per lineal inch, showed that the average particle diameter was 13 units. The kiln diameter inside is 10.2 ft., hence

$$Na.D = \frac{2,219 \times 10.2}{13 \times 786}\left(\frac{36.5}{100}\right)^{\frac{2}{3}} = 1.132$$

and F, by Table V, $= 0.67$.

(160) Attention is once more drawn to the emission and absorption factors which have been consistently used in connection with black body and gas radiation. These factors have been referred to in paras. (48*i*), (52), (63*c*), (88), (97), and (145). They are now gathered together for reference in Table XXVI.

Calculations in Detail for Stage (10).

(161) Table XXV is further explained by the calculation of stage (10) in detail. Taking an equivalent ring 1 ft. wide at the centre of the stage, a preliminary calculation is made in which the fluctuation of the lining temperature during each revolution of the kiln is neglected. (Unless otherwise stated " lining temperature " means the temperature of the inside face of the kiln lining.) An average value is obtained for the lining temperature from the condition that the heat which it takes in per minute must be equal to the heat which it gives out.

The preliminary calculation also gives the quantity of heat per minute which is stored in the lining and subsequently transferred to the underside of the material charge. A Fourier Series is used to find out by how much this quantity of heat is reduced when the fluctuation of the lining temperature is taken into account. A revised calculation of the rate of heat transfer in the equivalent ring is then made.

TABLE XXVI.

EMISSION AND ABSORPTION FACTORS AS USED THROUGHOUT.

		IN THE DRYING ZONE. STAGES (1) to (5)	FOR DRY MATERIAL (REMAINDER OF KILN)
1	Firebrick lining to kiln	0·80	0·90
2	Material chord	0·80	0·85
3	Material arc	—	0·75
4	Coke particles	—	0·90

(162) PRELIMINARY CALCULATION.—The flame, gas, and material temperatures are taken from Table XXV, and the lining temperature is assumed. The corresponding values of the black body radiation and the gas radiation expressed in B.T.U. per square foot per minute are as follows :

	Temperature. deg. Fah.	Black body radiation.	Gas radiation.
Flame	2,450	2,070	—
Gas	2,300	—	320
Lining	2,228	1,508	296
Material	1,400	346	89

(163) After obtaining further data from Tables XXIV and XXVI the calculation of the rate of heat transfer in the equivalent ring 1 ft. wide is made as follows :

	B.T.U. per foot run of kiln per minute.	
FLAME AND GAS TO UPPER LINING ARC.		
(12) $(2{,}070 - 1{,}508) \times 0.67 \times 0.9 \times 0.9 \times 25.12$ ..	7,661	
(13) $(320 - 296) \times 0.33 \times 0.9 \times 25.12$	175	
(14) $(2{,}300 - 2{,}228) \times \frac{1.19}{60} \times 25.12$	36	
		7,872
FLAME AND GAS TO MATERIAL CHORD.		
(16) $(2{,}070 - 346) \times 0.67 \times 0.9 \times 0.85 \times 6.37$ ..	5,627	
(17) $(320 - 89) \times 0.33 \times 0.85 \times 6.37$	413	
(18) $(2{,}300 - 1{,}400) \times \frac{1.30}{60} \times 6.37$	124	
		6,164
LINING RADIATION TO MATERIAL CHORD.		
(20) $(1{,}508 - 346 - 296 + 89.0) \times 0.33 \times 0.9 \times 0.85 \times 6.37$		1,535
LINING RADIATION TO MATERIAL ARC.		
(21) $(1{,}508 - 346) \times 0.9 \times 0.75 \times 6.89$..		5,405
		13,104
(22) Shell radiation loss, $0.072 \times 13{,}104$..		943

(164) The line numbers correspond to those in Table XXV. In line (12), for instance, the density factor for the coke particles is 0.67, the emission factor for the coke particles is 0.9, the absorption factor for the kiln lining with dry material is 0.9, and the length of the upper lining arc is 25.12 ft.

The heat given to the lining per minute is the sum of lines (12) to (14), or 7,872 B.T.U. The heat given up by the lining per minute is the sum of lines (20) to (22), or 7,883 B.T.U., which is nearly the same.

The heat quantity shown in line (21) is that stored in the firebrick lining. Since the kiln makes one revolution per minute the lining speed is 10.2π, or 32 ft. per minute, hence each square foot of the lining surface must absorb, and subsequently emit, $\frac{5{,}405}{32} = 169$ B.T.U. during each cycle or kiln revolution.

(165) The storage of heat by the kiln lining was dealt with in paras. (54) to (59) in connection with the 200-ft. kiln. A single lining block 1 ft. square was considered. In stage (10) of the 400-ft. kiln such a block would receive heat for 0.785 minute and reject heat for 0.215 minute. The temperature difference between the lining of the lower arc and the material is $2{,}228 - 1{,}400 = 828$ deg. F., hence the value of R (the rate of heat transfer in B.T.U. per square foot per minute per deg. Fah.) is

$$\frac{169}{828 \times 0.215} = 0.95$$

Similarly the temperature difference between the flame and the lining of the

upper arc is 2,450 — 2,228 = 220 deg. F. Hence the value of Q (the rate of heat transfer in B.T.U. per square foot per minute per deg. Fah.) is

$$\frac{169}{222 \times 0.785} = 0.97$$

It may be remarked that the fluctuation of the lining surface temperature is caused by part only of the heat listed in lines (12) to (14). Some of the heat is not supplied to the lining at flame temperature, but the error thereby introduced into the value of Q, is probably very small.

(166) A Fourier Series is now used to calculate the fluctuation of the block surface temperature during each cycle or kiln revolution, and the result obtained is shown by Fig. 29.

As a lining block passes through the upper arc its surface temperature is seen to rise from 1,928 deg. F. at *A* to 2,346 deg. F. at *B*. On passing under the material its surface temperature falls, reaching finally 1,928 deg. F. at *C*. The following figures are also derived :

		deg. F.
(*a*) Average lining surface temperature	(upper arc) =	2,282
(*b*) ,, ,, ,, ,,	(lower arc) =	2,023
(*c*) ,, ,, ,, ,,	(circle) =	2,226

The average temperature difference between the flame and the lining in the upper arc is now reduced to 2,450 — 2,282 = 168 deg. F., and the heat received by the lining block 1 ft. square during each cycle is 0.97 × 0.785 × 168 = 127.9 B.T.U.

The temperature difference between the material and the lining in the lower arc is reduced to 2,023 — 1,400 = 623 deg. F., and the heat emitted by the lining block during each cycle is

$$0.95 \times 0.215 \times 623 = 127.3.$$

The preliminary calculation, using the full temperature differences, gave the value 169 [see para. (164)], hence the storage factor is

$$\frac{127.6}{169.0} = 0.75.$$

(167) Revised Calculation of Stage (10).—The relevant temperatures, and the black body and gas radiations due to them, expressed in B.T.U. per square foot per minute are as follows :

	Temperature F.	Black body radiation.	Gas radiation.
Flame	2,450	2,070	—
Gas	2,300	—	320
Lining, average for upper arc	2,282	1,633	314
,, ,, circle ..	2,226	—	—
,, ,, lower arc	2,023	1,097	—
Material	1,400	346	89

(168) The detail of the rate of heat transfer in the equivalent ring 1 ft. wide at the centre of the stage is shown below.

	B.T.U per foot run of kiln per minute.	
FLAME AND GAS TO UPPER LINING ARC.		
(12) $(2{,}070 - 1{,}633) \times 0.67 \times 0.9 \times 0.9 \times 25.12$ ..	5,957	
(13) $(320 - 314) \times 0.33 \times 0.9 \times 25.12$	45	
(14) $(2{,}300 - 2{,}282) \times \frac{1.19}{60} \times 25.12$	9	
		6,011
FLAME AND GAS TO MATERIAL CHORD.		
Lines (16) to (18) as before		6,164
LINING RADIATION TO MATERIAL CHORD.		
(20) $(1{,}633 - 346 - 314 + 89) \times 0.33 \times 0.9 \times 0.85 \times 6.37$		1,707
LINING RADIATION TO MATERIAL ARC.		
(21) $(1{,}097 - 346) \times 0.9 \times 0.75 \times 6.89$		3,493
		11,364
(22) Shell radiation loss $0.072 \times 11{,}364$		811
		12,175

(169) These figures are entered on Table XXV, where the heat supplied to the kiln lining per minute is seen to be equal to the heat given out.

In lines (12), (13), (14), and (20) the revised calculation is based on the average temperature of the upper lining arc and in line (21) the revised calculation is based on the average temperature of the lower lining arc, hence the storage factor for the kiln lining is not now used directly.

In line (13) the gas radiation is assumed to act between the coke particles, a factor of $(1-0.67)$ being used. The shielding effect of the coke particles is somewhat over-estimated, as shown in paras. (138) to (142), but the total quantity of gas radiation is small.

Approximate Method for Calculation of Stage Lengths.

(170) The lining storage factors for stages (6) to (12), where the material is dry, are given in Table XXV, line (10), They have been obtained in this instance by taking a relatively large number of terms of the Fourier Series, and are probably representative for a normal kiln.

It is convenient to express the storage factor for any stage in terms of temperature difference. Suppose the difference between the flame temperature and the material temperature to be denoted by A, and the difference between the average surface temperatures of the upper and lower lining arcs by X, then the fractional loss of storage due to the fluctuation of the lining surface temperature can readily be shown to be $\frac{X}{A}\cdot$ Hence the storage factor is $1 - \frac{X}{A}\cdot$

Inserting the figures of stage (10), for instance [see para. (167)], we have

$$\text{storage factor} = 1 - \frac{259}{1{,}050} = 0.753.$$

On proceeding to calculate the rate of heat transmission in any stage where dry material occurs the value of A will be known, and if the storage factor is assumed the value of X is also known. The calculation then proceeds by trial and error; values for the average surface temperatures of the upper and lower

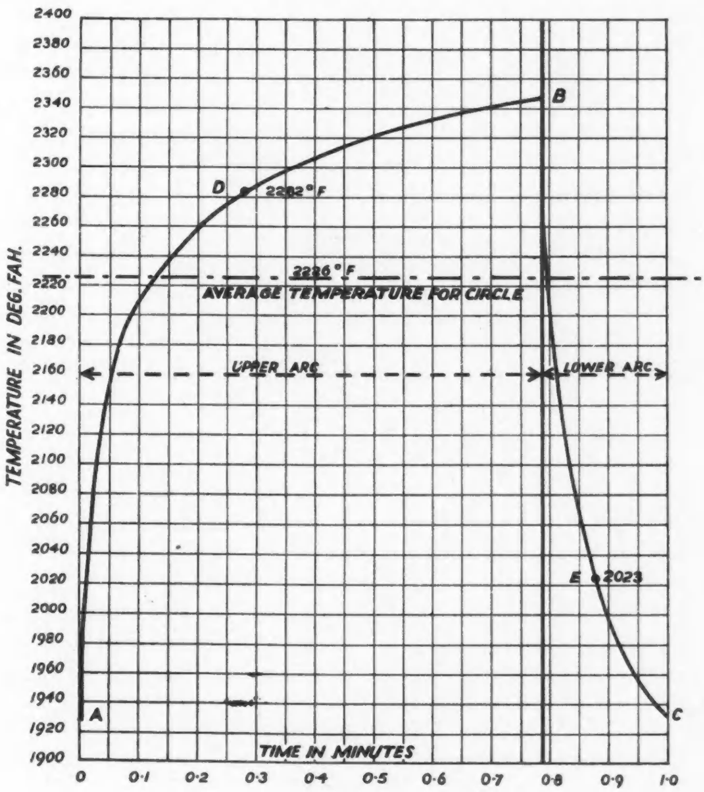

Fig. 29.

lining arcs are assumed, a condition being that their temperature difference must be equal to X.

The Kiln Dead End.

(171) It remains to consider the heat exchange which takes place in stages (13) and (14). In stage (13) the clinker is raised in temperature from 1,850 deg. F.

to 2,450 deg. F. by the exothermic reaction. In addition there is a shell radiation loss of 0.10 per cent. for which heat must be provided, see para. (159). In stage (14), as will be deduced from paras. (114*e*) and (116), the shell radiation loss is 0.43 per cent.

A diagram of the two stages is shown in Fig. 30. Heat is supplied to them by end-on radiation from the incandescent coke particles in stages (12) and (11), and by the fall of clinker temperature which takes place in stage (14). Heat is taken from the two stages by shell radiation and by the incoming air, which is heated. A satisfactory heat balance is obtained by assuming that the fall of the clinker temperature in stage (14) is 230 deg. F.; the figures are given in para. (172).

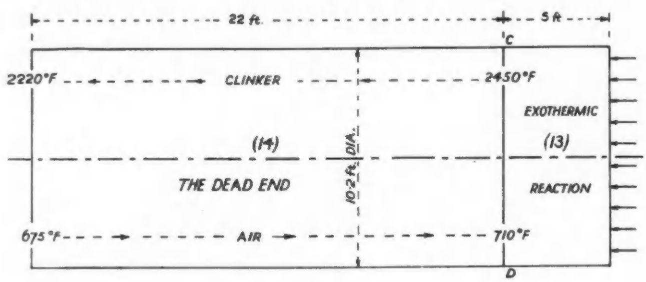

Fig. 30.

(172) HEAT SUPPLY TO STAGES (13) AND (14).

	Per cent.
(*a*) By radiation from the incandescent coke particles	0.25
(*b*) By a fall in the clinker temperature from 2,450 deg. to 2,220 deg. F.	0.46
Total	0.71

HEAT TAKEN FROM STAGES (13) AND (14).

(*c*) By shell radiation loss in stage (13)	0.10
(*d*) By shell radiation loss in stage (14)	0.43
(*e*) By heat given to air in stage (14) ($Hc = 0.68$)	0.18
Total	0.71

The method of calculation was explained in connection with the 200-ft. kiln in paras. (100) to (102). In line (*a*) the mean lining and clinker temperature to which the flame radiates is taken at 2,335 deg. F.

(173) One or two minor points remain to be cleared up. Referring again to the end-on radiation from the coke particles of 0.25 per cent. in line (*a*), 0.10 per cent. is assumed to balance the shell radiation in stage (13) and 0.15 per cent. is radiated into stage (14) [see para. (116*e*)]. The shell radiation loss in stage (14) is 0.43 per cent.; hence, after deducting the 0.15 per cent., a loss of 0.28 per cent. remains which is accounted for in para. (115).

Time of Combustion in Kiln.

(174) From the gas velocities given in line (4) of Table XXIV and from the length of the combustion zone (69.1 ft.) the average period of combustion appears to be about 2.91 seconds. This compares with 1.56 seconds for the 200-ft. kiln [see para. (104)].

Summary.

(175) The calculations relating to the 400-ft. kiln occur in Parts VI, VII and VIII.

PART VI.—A general description of a wet process rotary kiln 400-ft. long is given, the clinker output being 15½ tons per hour and the standard coal consumption 24.5 per cent. At the upper end of the kiln 648 chains, each 9 ft. 6 in. long, are fitted. Various figures which relate to the working of the kiln are listed, and the stages into which the kiln is divided for calculation purposes are described.

The dry coal analysis is given, also the weight of the gases per pound of dry coal and the heat content of the kiln gases at various temperatures reckoned above 60 deg. F.

Heat balances for the kiln and cooler are obtained. The kiln heat balance is then rearranged in order to show in proper order the heat which has to be transmitted to the material as it travels down the kiln.

The sources of the heat supply are 11.32 per cent. by radiation from the incandescent coke particles, 1.35 per cent. from the exothermic reaction, and 13.90 per cent. due to the fall in temperature of the kiln gases from 2,450 deg. to 500 deg. F.

(176) The average gas composition, weight, velocity and temperature in each of the stages (1) to (7) is next worked out, and values of the convection constant *Hc* and the P.D. values for gas radiation are obtained for each stage.

A description of the chains used, together with the method of arranging them in the kiln is given. A graph is provided from which the rate of heat transfer from the hot gases to the chains by convection can be obtained.

The rate of heat transmission to the chains by gas radiation is investigated, and in a typical example it is shown that the gas radiation per square foot of chain area can be obtained by using 0.55 P.D. instead of P.D. when the tables of gas radiation are used.

PART VII.—(177) A new method is described for obtaining the lining temperature and the chain temperature in the drying zone of the kiln. The symbol H_{con} is used to denote the rate of heat transfer between the kiln lining and the underside of the material expressed in B.T.U. per square foot per hour per deg. F. temperature difference. Values of H_{con} are deduced from figures previously given in connection with the 200-ft. kiln, and in the case of stage (1) confirmation is obtained by small-scale experiments which are described. The values of H_{con} finally adopted for stages (1) to (5) are 150, 91, 55, 35 and 22.

The extent to which the chains interfere with the gas radiation to the kiln lining is next investigated. In a typical example the loss due to shielding was 20 per cent., corresponding to a shielding factor of 0.80.

Similarly the gas radiation to any portion of chain was reduced by 15 per cent. due to the shielding effect of adjacent chains, thus giving a shielding factor of 0.85.

(178) The stage lengths in the drying zone, Nos. (1) to (5), were next calculated, and the heat transmission in stage (2), where chains occur, was worked out in detail.

The chains only project 1.9 ft. into stage (3), where their average temperature is 452 deg. F. If the chains were carried to the lower end of stage (3), i.e., to the point where the slurry is half dry, it was estimated that their maximum temperature would reach 770 deg. F. The effect would be to shorten the kiln by 48 ft.

If the kiln was not provided with chains it was estimated that its length would have to be increased by 207 ft. in order to obtain the same result in output and exit-gas temperature.

PART VIII.—(179) An estimation was made of the gas composition, weight, velocity, and temperature in each stage of the combustion zone, and the convection constants and the P.D. values for gas radiation were obtained.

A diagram showing the temperature of the material, the lining and the gas throughout the length of the kiln is provided. The average temperature of the chains, where they occur, is also shown.

The lengths of stages (6) to (12) were next calculated, and the heat transmission in stage (10) was worked out in detail. A diagram was obtained by the use of the Fourier Series which showed the fluctuation of the surface temperature of the lining during each revolution of the kiln.

(180) A method was explained whereby the stage lengths in any kiln could be approximately calculated, without the application of the Fourier Series, by using storage factors previously obtained for similar stages in other kilns.

The heat transmission in the dead end [stage (14)] was worked out showing that the clinker temperature fell 230 deg. F. in that stage, and the air temperature rose 35 deg. F.

The total length of the kiln as calculated was 391.7 ft. The length actually available for heat transmission was 385 ft.; the error was thus 6.7 ft., or 1.7 per cent.

Magnesia in Portland Cement. By H. E. SCHWIETE and H. ZUR STRASSEN. *Zement*, 1934, No. 9.—The question of the presence of free magnesium oxide in Portland cement is of great interest in connection with unsoundness due to this cause. The various ternary systems connecting CaO, MgO, Al_2O_3, SiO_2, and Fe_2O_3 have been examined. $CaO.MgO.SiO_2$ (monticellite) cannot exist in Portland cement in the presence of $3CaO.SiO_2$, except in spots where the silica is high due to unhomogeneity, because it decomposes according to the equation

$$CaO.MgO.SiO_2 + 3CaO.SiO_2 \rightarrow 2(2CaO.SiO_2) + MgO.$$

$MgO.Al_2O_3$ (spinel) cannot occur in cement clinker because it does not exist in equilibrium with $3CaO.Al_2O_3$. Spinel will not remain in equilibrium with either $5CaO.3Al_2O_3$ or $CaO.Al_2O_3$. Magnesia does not form mixed crystals with $\beta-$, $\gamma-$ $2CaO.SiO_2$ or $5CaO.3Al_2O_3$, nor does it combine with these compounds.

The compound $4CaO.2MgO.Al_2O_3.Fe_2O_3$ decomposes at 1,370 deg. C. into $4CaO.Al_2O_3.Fe_2O_2$ and MgO. In cooled clinker these two products of decomposition are not in equilibrium, but it is unlikely that the MgO would be resorbed in quickly cooled clinker. The destruction of cements high in magnesia is caused in all cases by the hydration of free magnesia. The speed of reaction of the MgO and water depends on the degree of burning.

Heat Balance of Rotary Kilns.

A series of diagrams given by Dipl. Ing. J. Koch in a recent number of *Zement* permit the heat balance of rotary kilns to be checked easily and quickly from records for CO_2, exit-gas temperature, clinker temperature, clinker produced, and fuel consumed. The diagrams are valid for average German coal, and show heat losses as well as the quantity of steam or electric power that can be generated from the heat contained in the exit gases. The diagrams are intended to assist the works manager in checking the reading of instruments, and it is not suggested that they are absolutely exact.

Figs. 1 and 2 illustrate conditions in a dry kiln and wet kiln respectively. The water content is taken at 7.5 per cent. and 40 per cent. Total heat consumed (lower calorific value of coal) is shown in calories per kg. clinker in relation to the quantity of exit gas independently of the CO_2 content. The diagrams also give curves for the exit-gas temperature. Variations of the specific heat of CO_2, steam, and nitrogen have been taken into consideration, but averages have been used as the possible error remains well within errors in recording the temperature.

Zero point for the temperatures varies according to the water content of the raw materials, and is arrived at by adding the theoretical heat consumption to the latent heat of the steam and deducting the heat content of the raw material. Zero in the two diagrams is accordingly arrived at as follows :

$445 + 75 - 5 = 515$ cal. for the dry kiln and

$445 + 610 - 20 = 1{,}035$ cal. for the wet kiln.

Variations in the heat content of combustion air are taken into consideration by giving the curve for 20 deg. C. as the horizontal, the 0 deg. C. line being inclined accordingly.

Point B in the diagrams is arrived at from coal consumption in cal. per kg. clinker and CO_2 per cent. It gives the quantity of exit gas including steam in nm^3, and also the theoretical temperature which would prevail if there were no losses through radiation of clinker.

If the exit-gas temperature actually recorded is marked on the vertical line c–B at point C, the distance C–B represents these losses through radiation and clinker. A separate scale showing the temperature of the clinker in relation to its heat content allows definition of D and C–D as loss through clinker. D–B represents radiation losses. The distance between c and B can now be read as follows :

c–G = theoretical consumption of heat,
G–H = latent heat in steam,
E–H = heat content of raw material at 15 deg. C. and water at 20 deg. C.
E–C = heat contained in exit gases,
C–D = heat carried away with clinker, and
D–B = radiation losses.

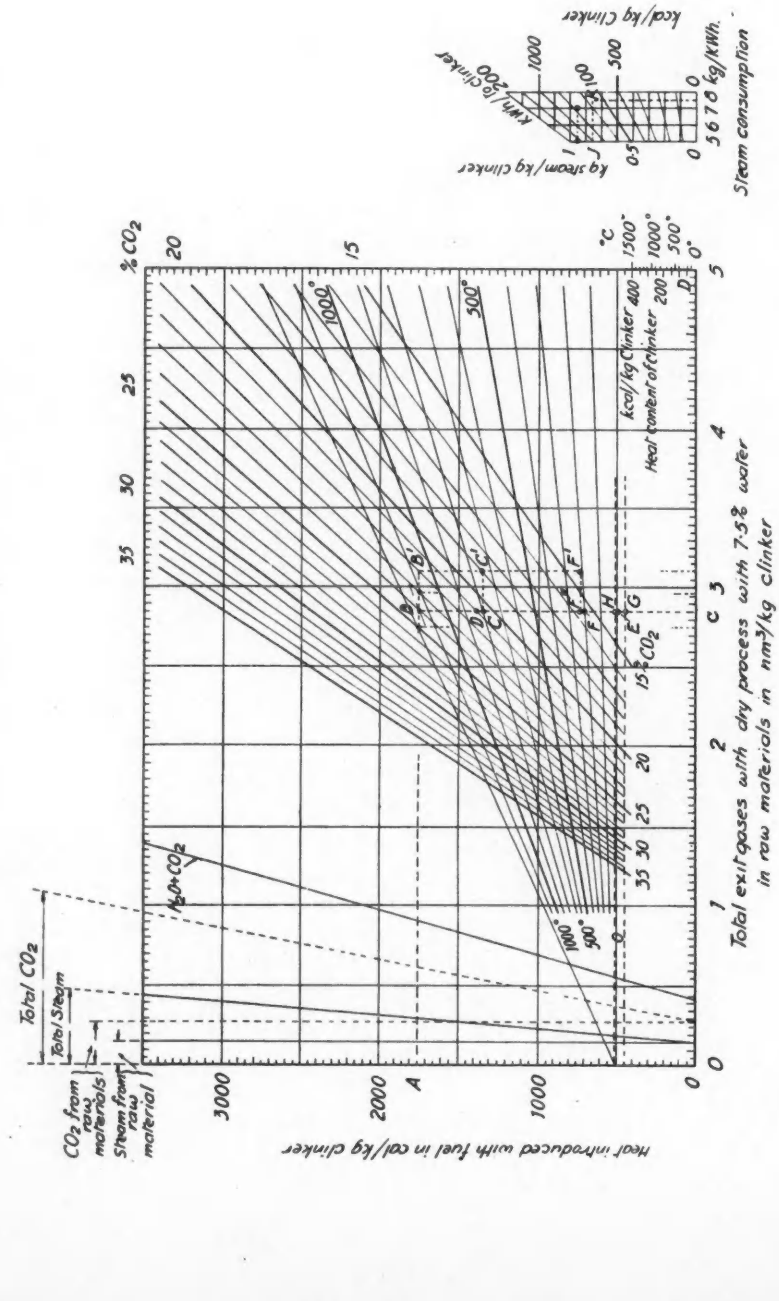
Heat introduced with fuel in cal/kg clinker
Total exit gases with dry process with 7·5% water in raw materials in nm³/kg clinker
% CO_2
kcal/kg Clinker
Heat content of clinker
°C
Total CO_2
Total Steam
CO_2 from raw materials
Steam from raw material
H_2O+CO_2
15% CO_2
Steam consumption
kg steam/kg clinker
kcal/kg Clinker
kWh/to clinker
kg/KWh.

Fig. 1.

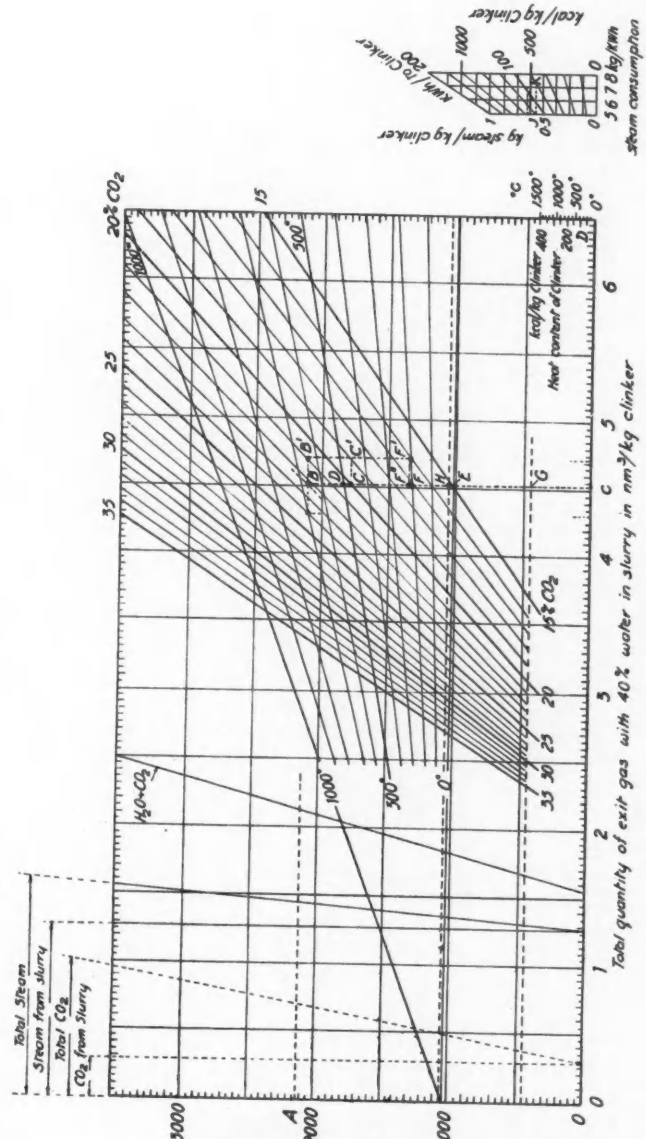
kcal/kg Clinker
kwh/10 Clinker
kg steam/kg clinker
steam consumption
Total Steam
Steam from slurry
Total CO_2
CO_2 from Slurry
Heat introduced with fuel in cal/kg clinker
Total quantity of exit gas with 40% water in slurry in nm³/kg clinker
kcal/kg Clinker
Heat content of Clinker
H_2O+CO_2

Fig. 2.

To illustrate conditions in exit gases in the case of waste-heat utilisation—it is only necessary to ascertain the temperature of the gases when leaving the boiler and to introduce this at point F. The distance between E and F represents the heat contained in final exit gases at, say, 200 deg. C., while F–C is the heat available for the generation of steam. This, however, neglects the influence of air leakage between kiln and boiler, which reduces the CO_2 content. This can be taken into account by fixing B′ at the CO_2 figure in question, determining F′ at 200 deg. C., and finally F″. C′ would indicate the lower temperature of the exit gases. Allowing for this reduction in the CO_2 and for an increase in the quantity of gas and for a lower temperature of gases entering boiler, the conditions may be illustrated as follows:

E—F″ = heat contained in exit gases of boiler.
F″—C = heat available for waste heat utilisation.

A small separate diagram on the same scale for cal. pr. kg. clinker shows the quantity of steam that may be generated by the calories represented by F″–C, and is based on 710 cal. pr. kg. steam, 10 per cent. radiation losses, 40 deg. C. feed-water, and steam of 15 to 20 atmospheres at a temperature of 350 deg. C. The same diagram gives kWh per ton of clinker for the steam generated by the heat contained in F″–C, the exit gases.

Fig. 3 shows conditions with varying water content. Zero in this case is at 440 cal. pr. kg., that is 445 for theoretical consumption minus 5 cal. pr. kg. for the thermal value of dry raw material. Values for different percentages of water are given on an inclined line starting from zero. The horizontal for each point represents the quantity of steam, while the vertical represents the corresponding latent heat minus the thermal value of water at 20 deg. C. The quantity of exit gases, excluding steam, is arrived at as before. A line drawn through A parallel to the percentage of water line, and of a length corresponding to the percentage of water, will give point B indicating the total quantity of exit gas at *c* and the theoretical temperature of exit gases at H. The vertical line c–B now gives the same information as in the previous diagrams, wrong air being allowed for by B′. B–H represents the latent heat of the steam. Slight discrepancies noticeable when comparing results from this diagram with the earlier ones are the result of differences in the specific heat; these become noticeable with varying water content.

Because of the importance of the CO_2 reading, Fig. 4 is provided, showing consumption in cal. pr. kg. in relation to the quantity of exit gas without steam depending on the CO_2. A set of curves shows theoretical combustion without excess air and combustion with 100 per cent. excess air. The CO_2 reading will immediately reveal the conditions of combustion. Percentages of oxygen present in exit gases at different states of combustion are given so that the CO_2 records can be immediately checked against oxygen readings. B and B′ refer to the same points as in the earlier diagrams.

The formula $\frac{B-C}{C-D} \times 100$ gives the quantity of excess air in percentages.

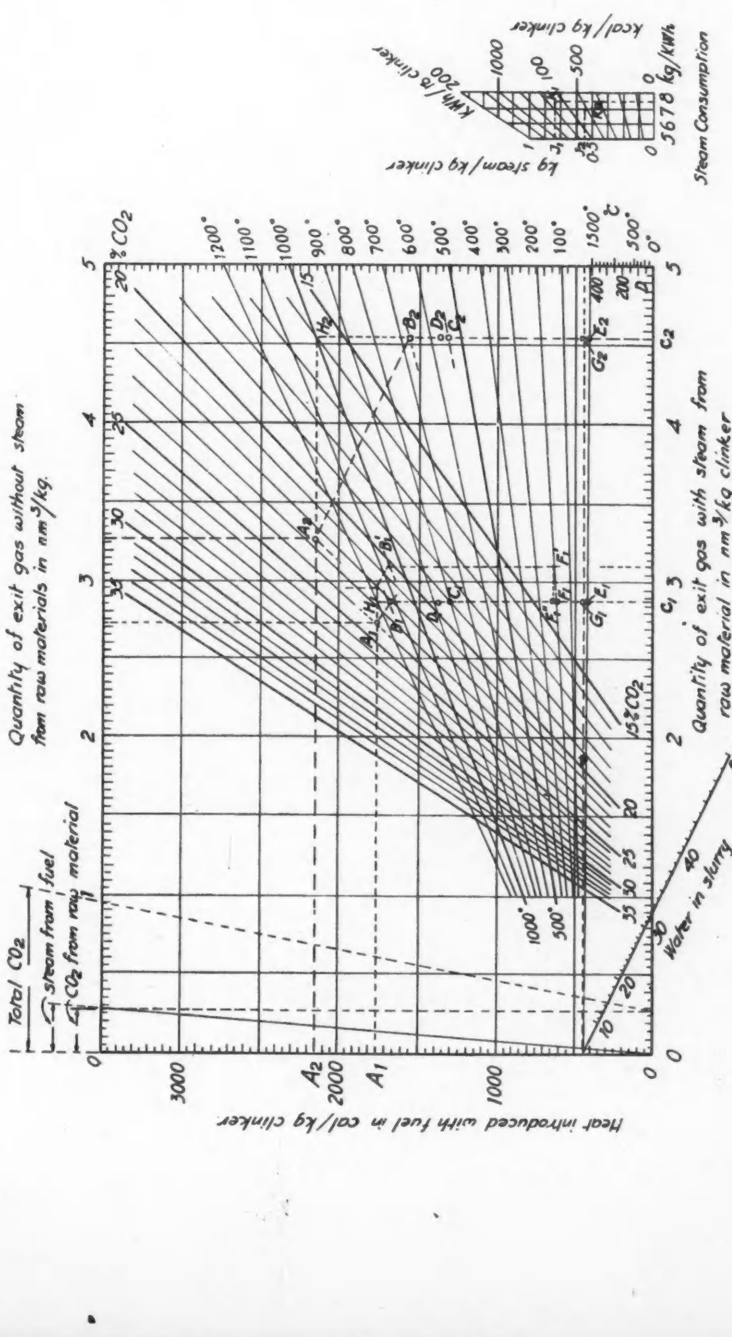
kcal/kg clinker
kWh/t clinker
kg steam/kg clinker
kg/kWh
Steam Consumption
Quantity of exit gas without steam from raw materials in nm³/kg.
Total CO2
steam from fuel
CO2 from raw material
Heat introduced with fuel in cal/kg clinker
Quantity of exit gas with steam from raw material in nm³/kg clinker
Water in slurry
% CO2

Fig. 3.

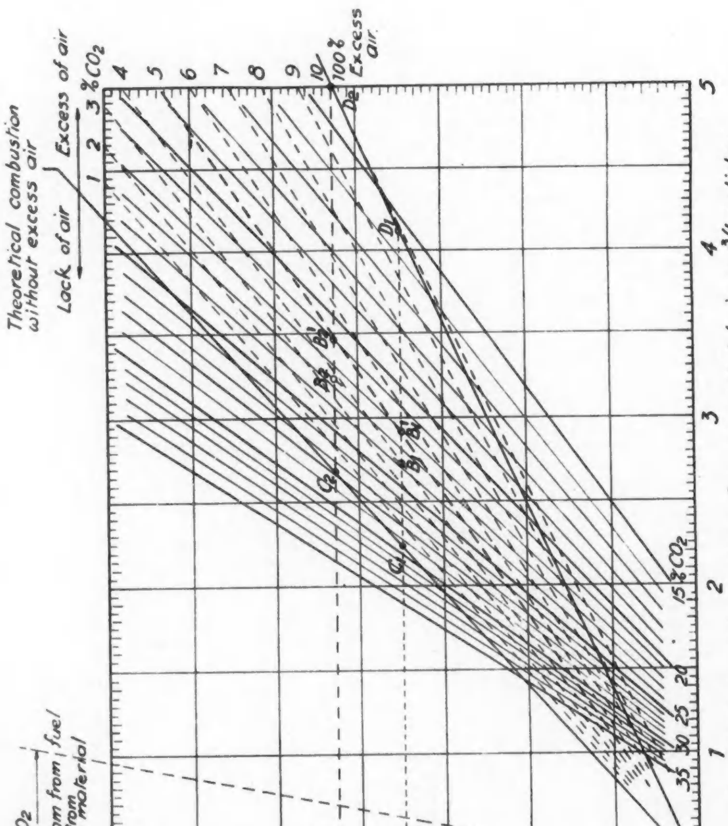
Theoretical combustion without excess air
Lack of air
Excess of air
Total CO_2
Steam from fuel
CO_2 from raw material
Heat introduced with fuel in cal/kg clinker
Quantity of exit gas without steam from raw materials in nm^3/kg clinker.
100% Excess air.
15% CO_2
% CO_2
3000
2000
1000
0
A_2
A_1
B_1
B_2
C_1
C_2
D_1
D_2

Fig. 4.

It is recommended that the CO_2 reading be checked by this method before using the diagrams giving the heat balance.

The examples illustrated in the diagrams are given below :

Line.		Dry kiln	Wet kiln.
	Heat consumption (cal. pr. kg. clinker)	1,750	2,145
	CO_2 at end of kiln (per cent.)	23.8	22.5
	Oxygen at end of kiln (per cent.)	3.9	3.8
	Excess air (per cent.)	25	25
	Quantity of gas at end of kiln (nm³ pr. kg. clinker)	2.87	4.52
	Temperature of exit gases (deg. C.)	800	475
E–C	Heat contained in exit gas (cal. pr. kg. clinker)	860	705
	Clinker temperature (deg. C.)	200	200
C–D	Loss of heat through clinker (cal. pr. kg. clinker)	40	40
D–B	Radiation losses :		
	CO_2 at entrance to waste-heat boiler (per cent.)	22	21
	Oxygen at entrance to waste-heat boiler (per cent.) ..	5.1	4.9
	Excess air at entrance to waste-heat boiler (per cent.) ..	36	33.5
	Quantity of gas at entrance to waste-heat boiler (nm³ pr. kg. clinker) ..	3.09	4.73
	Temperature at entrance to waste-heat boiler (deg. C.) ..	750	445
	Temperature at exit of waste-heat boiler (deg. C.)	200	200
E–F″	Loss in exit gases at 200 deg. C. (cal. pr. kg. clinker)	210	340
F″–C	Heat available for waste-heat utilisation (cal. pr. kg. clinker)	650	445
	Steam produced (kg. pr. kg. clinker)	0.825	0.57
	Steam consumption of turbine (kg. pr. kWh)	7.5	7
	Power generated (kWh pr. ton clinker)	110	81
c–G	Theoretical heat consumption (cal. pr. kg. clinker)	445	445
E–H	Heat content of raw materials at 15 deg. C. and water at 20 deg. C. (cal. pr. kg. clinker)	20	40
G–H	Latent heat in steam (cal. pr. kg. clinker)	75	610
D–B	Radiation loss (cal. pr. kg. clinker)	350	305

Lime and Dry Ice from Limestone. *Tonind. Zeit.*, 1934, No. 18.—There are considerable difficulties, due to the presence of impurities, in the way of using carbon dioxide for dry ice if it is obtained from the burning of coke or limestone in the ordinary way. The gas may be purified by passing it into a potash solution and subsequently heating the solution to recover the CO_2. This, however, is uneconomical. The Gillette Research Corporation has suggested a method whereby pure CO_2 and pure lime are produced. The former is converted into "dry ice," the temperature of which is about -80 deg. C., while the latter can be used in the chemical industry as it is free from the impurities present in the fuel and flue gases.

The limestone is burnt in vertical retorts of silicon carbide which have high conductivity. The CO_2 is drawn off from the centre and freed from dust before liquefaction. The principle of the production of "dry ice" is very simple. Pure CO_2 is liquefied by compression and then a portion is allowed to cool very rapidly by evaporation in a special apparatus. The drop in temperature caused by this is sufficient to freeze the rest to a fine loose powder which is afterwards compressed into blocks. "Dry ice" is extensively used in America instead of ice since it evaporates as it absorbs heat without going through the liquid state.

Heat of Hydration.

IN the latest report of the Association of Japanese Portland Cement Engineers, Messrs. Mitsuzo Fujii and Shiro Yamamura give details of the development of heat in setting cement for nine ordinary Japanese Portland cements and for a United States, a Danish, and a Japanese "high-strength" cement. The ordinary cements vary in lime ratio from 2.6 to 2.9, in silica ratio from 2.12 to 3.15, and in alumina to iron ratio from 1.53 to 2.47. The tensile strengths for 3 : 1 mortar cover the following ranges: 24 hours, 336 to 481 lb. per square inch; 7 days, 393 to 555 lb. per square inch. The compressive strengths at 7 days vary from 5,350 to 9,670 lb. per square inch. The finenesses of the samples were determined by separation into various fractions by elutriation. The residues on the 4,900-mesh sieve (approximately B.S. 170×170) varied from 0.9 to 4.7. Recasts of the analyses according to the American method showed that the tricalcium silicate varied from 37.12 to 66.20 per cent. and the tricalcium aluminate from 8.02 to 11.67 per cent.

Seven of the cements showed very similar heating curves. There is a small initial rise immediately after gauging, followed by a second rise, and after a pause a third rise when the temperature attains a maximum and then drops gradually. Two clear steps can be noted at the second rise for some of the cements. The maximum temperature was attained after from 5 to 7½ hours. In the two other cases the rises were slower; in one the maximum was reached at 10 hours while the other, after a small rapid liberation of heat, remained at an almost constant temperature for 8 hours and then rose to a maximum at 17 hours. There does not seem to be a direct relation between rise of temperature and strength. The cement which gave the greatest temperature rise was the strongest, but cements with a maximum of 90 deg C. at 17 hours and 10 hours were better than those with a maximum of 95 deg. C. at 6 hours and 100 deg. C. at 17 hours.

The heating curves of the "high-strength" Portland cements are very similar to those of the normal cements, except that they show a much greater rate of heating. All three have a rapid rise between 3 and 4½ hours after gauging to a temperature of 105 to 107 deg. C., and then a gradual fall. The lime ratios of these cements varied from 2.94 to 3.08, silica ratios from 2.06 to 2.77, and alumina-iron ratios from 2.01 to 2.82. The finenesses were 0.4 to 1.2 per cent. residue on the 4,900-mesh sieve. The tensile strengths were: 24 hours, 436 to 529 lb. per square inch; 7 days, 589 to 636 lb. per square inch. The compressive strengths were: 24 hours, 4,990 to 6,470 lb. per square inch; 7 days, 8,880 to 10,530 lb. per square inch. These figures are for 3 : 1 sand mortar.

With increase of the amount of the gauging water the development of heat is uniform and slower and the rate of heating lower. The same results are obtained by storing the cement in air containing CO_2.

The shape of the heating curve for the fraction 0 to 40 microns is the same as for the original cement. This fraction was obtained by separating the grit by means of a large air elutriator.

Additions of $CaCl_2$ increase the development of heat, and the effect apparently reaches a maximum at 2 to 3 per cent. admixture. In all cases the second rise in the heating curve shrinks for additions of small amounts of $CaCl_2$, while for additions of 4 to 5 per cent. the second rise reappears, but is very irregular.

The character of the heating curves for aluminous cement differs from that of Portland cement. The temperature rises but little for about 4 hours, then within a very short time there is a sudden liberation of heat and the curve rises almost vertically to over 100 deg. C. After this there seems to be no further liberation of heat and the curve falls away gradually as the material cools.

The heating curves were obtained by allowing the image of the mercury to trace out a graph on a strip of sensitive material moved by clockwork in a camera. The actual curve is the line traced out by the top of the mercury column and divides the photograph into a light and a dark portion. The thermometer was set in the middle of the cement paste, which was contained in a small zinc cylinder in a Dewar flask. The whole was well insulated with thick cork. The amounts of cement were so chosen that the maximum temperature did not rise much above 100 deg. C.

Research on Portland Cement.

The following notes are taken from a report of a recent meeting of the Verein der Freunde des Kaiser-Wilhelm-Instituts für Silicatforschung, held at Berlin. H. E. SCHWIETE reported that a hydrate with nine molecules of water had been isolated and was converted to $2CaO.Al_2O_3.7H_2O$ by drying over calcium chloride. A 5-hydrate was obtained by drying over phosphorous pentoxide at 105 deg. C. The 5-hydrate is stable up to 150 deg. C ; above this it slowly loses water until a trihydrate is obtained, and at still higher temperatures the monohydrate is formed. The monohydrate is stable at temperatures of over 400 deg. C, and loses its water only at 700 deg. C. The existence of a 13-hydrate also is probable. From X-ray investigations it was found that the hydrates could be divided into two groups according to the similarity of the chief lines in their diffraction patterns. One group contained the 9-hydrate, 7-hydrate and 5-hydrate, the other the tri- and monohydrates. The higher hydrates (9, 7, 5) are considered to be basic meta-aluminates with the univalent anion $[Al(OH)_4]$. The 5-hydrate is the most stable compound. The 9-hydrate and 7-hydrate have loosely held water which is therefore considered as H_2O-groups attached to the Ca-ion. By the loss of one molecule of water from the anion $[Al(OH)_4]$ the univalent anion $[AlO(OH)_2]$ is obtained which seems to form the nucleus of the trihydrate. By the loss of one molecule of water the trihydrate is converted into the monohydrate which is a basic calcium salt of the formula $Ca\begin{cases} OH \\ AlO_2 \end{cases}$.

Dr. L. Forsen expressed the opinion that alite ($3CaO.SiO_2$), belite (β-$2CaO.SiO_2$), and celite ($4CaO.Fe_2O_3.Al_2O_3$) are the most important constituents of cement

clinker. Alite gives the hydraulic properties to Portland cement and the aluminate accelerates the reactions. According to this the maximum lime content possible is obtained from the formula.

$$3CaO.SiO_2 + x(4CaO.Al_2O_3.Fe_2O_3) + y(3CaO.Al_2O_3).$$

Equilibrium is not obtained in practice on account of the short time of heating, hence it is better to use the formula

$$3CaO.SiO_2 + x(4CaO.Al_2O_3.Fe_2O_3) + y(nCaO.Al_2O_3)$$

and $CaO = 2.8 \times \%SiO_2 + 1.4 \times \%Fe_2O_3 + f(\%Al_2O_3 - 0.64 \times \%Fe_2O_3)$.

The factor f varies from 1.0 to 1.65 according to the raw material.

According to Dr. Sundius, $3CaO.SiO_2$ can take up small unknown amounts of aluminate in solution, and $2CaO.SiO_2$ can take up P_2O_5 and manganese; $2CaO.SiO_2$ can also take up as much as 10 per cent. $2MgO.SiO_2$ in solid solution. He considers that free aluminates do not occur in clinker, and that at least a part of the aluminate is in solid solution in the tricalcium silicate.

Expansion and Shrinkage of Cements.

In *Zement* (40/1933) Dr. Ing. O. Goffin and G. Mussgnug describe experiments on the expansion and shrinkage of cements. Investigations were limited to the influence of the chemical composition of clinker on expansion during water storage and shrinkage during storage in air or combined storage. This provides for the examination of the influence of free lime, silica content and silica ratio, gypsum and $CaCl_2$, and fineness.

Measurements were made on 71 mm. standard cubes of 1 : 3 mortar with cements of different characteristics. The optical method was used. To obtain comparable results the different mortars were prepared to the same consistency. To ascertain the water necessary in each case tests were made with 1 : 3 mortar as well as with neat cement. It is interesting to note that no fixed relationship was found between the water necessary for neat cement and concrete.

The cubes (four for each test) were stored in water, in air, and combined storage (one day humid air, six days water, then air), and were measured after seven, twenty-eight, sixty and ninety days. Results showed marked expansion with increased content of free lime, whilst shrinkage was low. Silica content and silica ratio appear to be of little importance, while results from two comparable kinds of clinker seem to prove slightly increased shrinkage in the case of high silica content (silica ratio 2.7 as against 1.5). Gypsum added beyond 4 per cent. increased expansion and decreased shrinkage. $CaCl_2$ increased shrinkage whilst expansion was hardly influenced.

The fineness to which the cement is ground is of importance. Fine cements showed greater shrinkage, but this is not the result of any larger quantity of water used, as in one case the quantity of water needed was the same for cement ground to 1 per cent. and 12 per cent. residue on the 4,900-mesh sieve with mortar of the same consistency. Shrinkage here seems to be influenced by the larger surface of the more finely ground cement.

The results obtained are not related to construction work as the conditions of the experiments were not representative, and storage in comparatively dry air caused the shrinkage to be exceptionally high.

New Cement Works Near Lewes.

A NEW Portland cement works equipped by Edgar Allen and Co., Ltd., who were the main contractors, has been built at Rodmell, near Lewes, Sussex, for Cement Industries, Ltd., now the Alpha Portland Cement Co. The works (Fig. 1) was ready to commence operation in October, 1932. Although only one unit of plant was installed in the first instance, consideration was given throughout to the probability of future extension.

Raw Materials.

In common with most cement factories in the south of England, the raw materials employed are chalk and clay. The calcium carbonate content of the chalk varies from 97 per cent. on the higher levels to about 50 per cent. at the foot of the hills. An excavator of the dredger type, supplied by Messrs. M. Steenbrugge and Co., is used for digging the clay ; this machine is seen in Fig. 2,

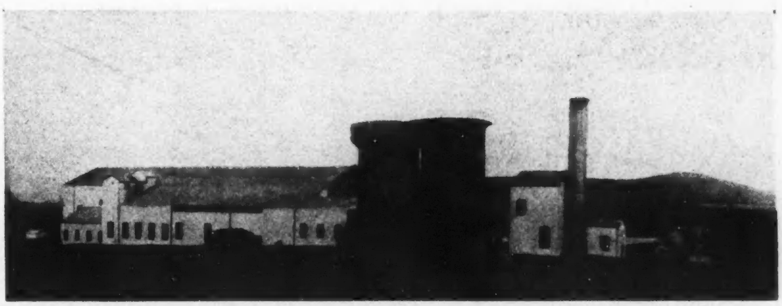

Fig. 1.

from which it will be observed that the digging is done mostly under water. The track on which the excavator runs is provided with a turntable so that the machine can be swung round when required and used for removing the top soil. When digging clay the machine travels along the face, and at each new journey the jib is lowered so that the buckets take a fresh cut about $\frac{1}{2}$in. thick. The clay is thus removed in thin layers over the whole depth of the pit. The jib is arranged to move round two pivots so that the part of the jib along which excavation takes place is always at the same angle, and the depth of cut is therefore the same along the whole face. The excavator buckets discharge into a hopper at the back of the machine. This hopper is fitted with a flap, which is operated by the attendant and allows the clay to fall into wagons which are hauled by a 2ft. gauge continuous rope haulage system to the washing plant. The chalk is excavated by a steam bucket excavator, and brought to the washing plant on a 4ft. $8\frac{1}{2}$in. gauge track by a Diesel locomotive.

Fig. 2.

Fig. 3.

The washing plant consists of two Edgar Allen 18-ft. washmills working in series. The clay is tipped directly into the first washmill, but the chalk is first reduced by passing it through a set of Stag kibbling rolls from which it falls into the washmill in lumps of about 5in. downwards. From the first washmill the slurry is elevated by a bucket elevator and fed into the second washmill for further reduction. This washmill is of similar design to the first but is fitted with finer screens. Finally the slurry runs by gravity to a tube mill where it is ground to a fineness of about 5 per cent. residue on the 170-mesh sieve.

The mixture of chalk and clay is, in the first instance, controlled at the first washmill by regulating the number of wagons tipped of the respective raw materials. With a little experience it is possible to get very close to the pro-

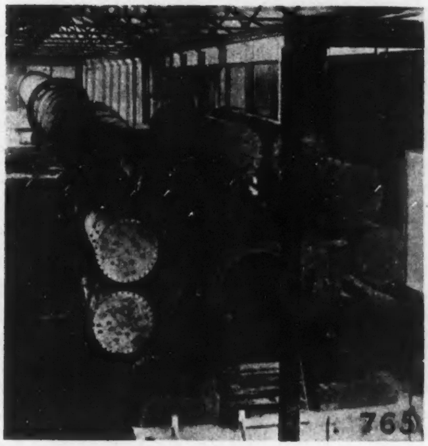

Fig. 4.

portions required, but adjustment is made by providing three storage tanks into which the slurry is pumped from the discharge sump of the tube mill by means of a Stag centrifugal pump ; one tank contains slurry of the correct mix ready for the kiln, the second is being filled with slurry, and the contents of the third are being checked by the laboratory staff. If this is found to be, say, high in calcium carbonate, the requisite amount of low carbonate slurry is washed and pumped into the silo for the purpose of correction. For correction purposes it is also possible to mix the contents of any two tanks by means of valves and piping interconnecting the three tanks. Each tank is fitted with a series of air pipes through which compressed air is blown at regular intervals to agitate the slurry thoroughly and prevent settling of the solids. The compressed air is supplied by a Broom and Wade compressor of the horizontal rotary type direct coupled to its driving motor.

A three-throw Stag pump of the plunger type delivers finished slurry to main storage tanks in the kiln department. Water for the washmill is supplied by a three-throw Pearn pump which delivers water from a nearby stream into an angular storage tank incorporated in the design of one of the slurry tanks.

Two steel tanks, each having a capacity of about 16,000 cu. ft. of slurry, are provided for storage purposes. These tanks are of the same design but larger than the correction tanks. With this storage capacity of finished slurry, the washmill section of the works can be closed down over week ends.

Two sets of Stag centrifugal pumps are provided to deliver the slurry to the kiln, one set being a standby. Regulation of the slurry feed is by a spoon feeder

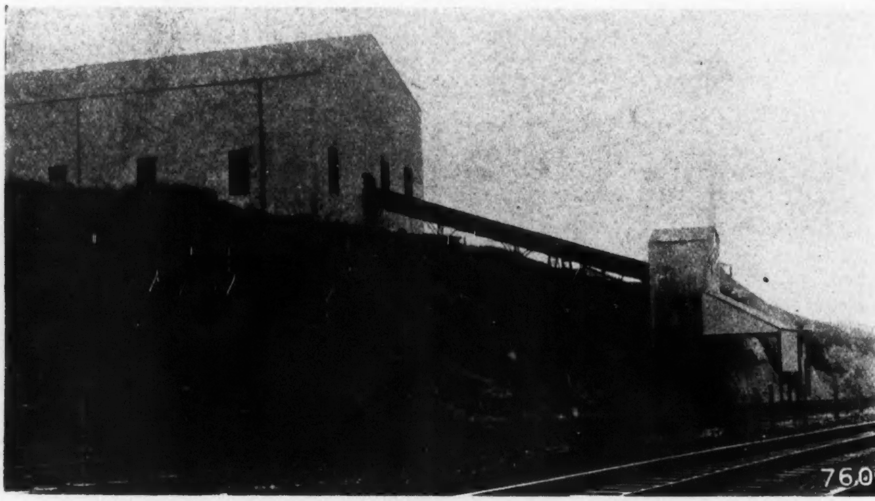

Fig. 5.

driven through a worm reduction gear by a variable-speed motor. The latter is controlled by the kiln operator from the firing platform.

The Kiln.

The kiln has an output of 60,000 to 70,000 tons of clinker per annum, and there is room to accommodate two further units. The kiln is 9ft. in diameter by 235ft. long. The shell is lined with firebrick and has an enlarged section of 10ft. 6in. diameter at the clinkering zone.

The kiln is carried on four cast steel tyres supported on chairs which are riveted to the shell. It is driven by a variable-speed motor direct coupled to an enclosed reduction gear. The speed is further reduced by open-spur gearing, and the final drive is through a spur wheel, mounted on the kiln shell, and transmitting motion to the kiln by tangential spring plates. The drive is illustrated

in Fig. 3. The kiln is of the Edgar Allen " Tiger " type, and is fitted with a set of recuperator tubes secured rigidly at one end to the kiln shell and hinged at the other to allow for expansion. Clinker enters the tubes through openings in the shell at the end of the kiln, and travels up through the tubes assisted by spirals fitted inside. In addition, cascaders inside the tubes lift the hot clinker, thus exposing it to the air and reducing its temperature, and at the same time heat the air used for combustion. Fig. 4, taken during the erection of the plant, shows the discharging arrangements. A reduction in fuel consumption is obtained by this type of kiln as against older types with separate coolers, inasmuch as there is less leakage of cold air into the system, whiie construction costs are reduced by having a combined unit and less head room is required.

Coal is received at the works sidings and discharged into a receiving hopper. Under the hopper a feeder is provided to deliver the coal to a vertical steel-cased elevator. The elevator discharges the coal on to a band conveyor, which takes

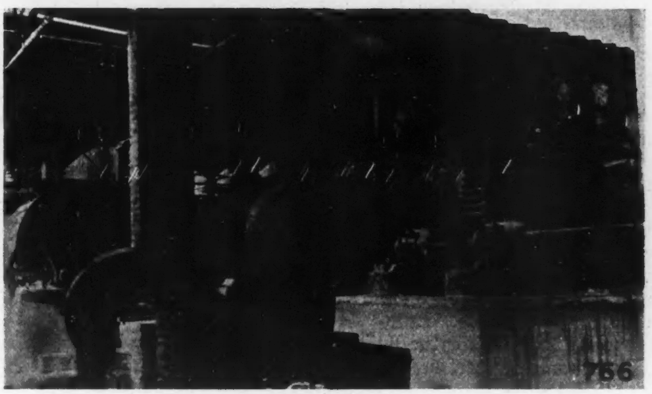

Fig. 6.

it into the main coal storage shed where it is handled by a travelling crane and grab. The coal, which may have a moisture content of 16 per cent., is dried in an Edgar Allen double-shell rotary dryer, passing over a magnetic separator to remove any tramp iron. Reduction of the coal to the requisite fineness is accomplished in a Rexman rod mill working in conjunction with a Stag air separator. Fig. 5 shows the first stage of the coal-handling plant.

Clinker and Cement Handling and Storage.

Coal, clinker and gypsum are stored in a covered building with retaining walls on all sides and cross divisions to separate the various materials. The building, which is 60ft. wide, is served by a crane running the full length. Wet coal is dumped within reach of the crane by the conveyor. The crane is thus able to distribute the coal, and when necessary mix different qualities of coal. The crane also feeds the raw coal hopper forming a storage for the coal drying

plant. The clinker discharged from the kiln is conveyed by an Edgar Allen swing tray conveyor and elevator to a suitable height for delivery into the storage area. Previous to dumping it passes over an automatic weigher which registers the output of the kiln. A small area is reserved for gypsum.

The clinker mill house can be seen in Fig. 6. On the left one of the two Rexman rod mills can be seen. These two mills were used as preliminary grinders, their product being screened over two Edgar Allen—Allis-Chalmers vibrating screens which return the rejects to the rod mills and pass the fines to the tube mill for final reduction.

From the tube mill the cement is delivered by gravity to a Fuller-Kinyon stationary pump. The plant consists of a pump for moving the material, a pipeline for the transport of the material, and switching valves in the pipeline for diverting the material to any desired point.

In order to expedite erection of the factory and reduce the initial construction costs, the usual type of cement silo was not built, but provision was made for the construction of such silos at a future date. For the storage of the cement a set of four specification bins was constructed into which the Fuller-Kinyon pipeline delivered the cement, and from which the cement was extracted by another Fuller-Kinyon pump of the portable " unloader " type.

Packing and weighing of the cement is by a Bates valve packer with three delivery spouts. The capacity of this machine is about 35 tons per hour.

The works are close to the Southern Railway's main line from London to Newhaven. A new roadway was constructed to connect the packing department with the Lewes-Newhaven road. Facilities are therefore available for despatch by rail or road. It was contemplated that in the future a scheme would be put in hand to make use of the river Ouse as a third means of transport.

The works are electrically driven by purchased power. The current is brought into the works sub-station at 11,000 volts and stepped down to 440 volts. A second supply is provided at the quarry. The whole of the electrical equipment of the works, of a total of 1,600 h.p., was sub-let to the General Electric Co., Ltd., and the cable work and erection of electrical plant were carried out by the Electric Super Service Co., Ltd.

The foundation work for the building was carried out by Messrs. E. D. Winn and Co., Ltd., and the steel buildings were supplied and erected by The London and Wales Steel Construction Co., Ltd.

Recent Patent Applications.

406,530.—N. Nielsen : Rotary-kiln plant for the manufacture of cement.
402,810.—Gypsum Mines, Ltd., and R. Collins : Plasters and cements.
402,933.—E. McGivern : Buckets or skips for handling cement.
404,451.—A. J. Seed : Cement and process for making same.

Trade Notice.

Draglines for South Africa.—Included in the March shipments of Ruston-Bucyrus excavators were three 37-B diesel draglines, with 45-ft. booms and 1½-yd. buckets for the Department of Irrigation, South African Government. Tropical housing was supplied for each machine, and equipments for converting a dragline to shovel with 1½-yd. bucket and to grabbing crane with 1-yd. bucket were also included. These machines are for the Vaal Hartze irrigation project, and will be digging irrigation canals south of Kimberley at an altitude of about 4,000 ft.

Improved High-capacity Shaft Kilns.

THE burning of cement in shaft kilns is attended by difficulties due to sticking in the kiln hindering or preventing the descent of the material. This type of sticking occurs when high air pressure is used to obtain a large output. With a view to minimising this difficulty, the "Krupp-Grusonwerk-Andreas" high-capacity shaft kiln has been developed, in which a portion of the air is blown into the kiln through the side through two sets of nozzles and so cools the kiln walls

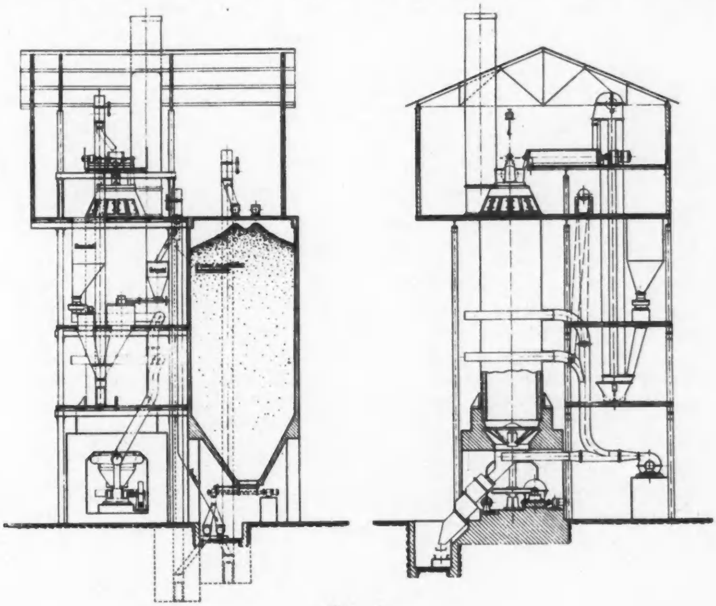

Fig. 1.

at the point where the sticking occurs. A kiln constructed thus is claimed to work very uniformly and to produce a good clinker, and the attention it requires compared with the older type of kiln is claimed to be considerably less. A further improvement in the working of the shaft kiln has been made by the introduction of a machine for producing small moulded briquettes of a suitable shape.

In burning Portland cement not only must a good uniform raw material be used but the raw material mixed with the fuel must also be moulded into the smallest possible sizes. These small pieces burn completely through more easily and therefore give a better clinker with less underburnt material. Although the small briquettes give the most gas-permeable charge possible, they should contain very little fine material or dust. This dust fills the spaces between the briquettes and consequently the burning process in the kiln is reduced. In

practice it has been found that briquettes of about 30 to 35 mm. diameter and 30 to 40 mm. long are the most suitable for burning in the shaft kiln.

Up till now it has been very difficult economically to prepare large quantities of suitable briquettes with the machinery available at present. The new mechanical equipment consists of an edge-mill, the baseplate of which is provided with holes 30 to 35 mm. in diameter; this machine produces sufficiently solid briquettes out of somewhat plastic raw material without making dust. The edge-mill must be specially converted for this purpose, particularly with respect to parts such as the scraper, etc., which are important for producing the briquettes in the desired manner. These edge-mills have given good results in practice, and kilns are in operation which produce 120 to 140 tons of clinker per 24 hours with this equipment. The idea of using edge-mills for this purpose originated with Messrs. Schwenk, of Ulm, and the sole rights of manufacture have been acquired by Krupp-Grusonwerk.

In this process the mixture of raw material and fuel is fed by a mixing worm which moistens it at the same time. The briquettes which pass through the edge-mill plate fall on to a rotating conveyor, which is driven directly from the edge-mill and is adjustable so that the briquettes are cut in the most advantageous manner for burning.

Fig. 1 shows a general view of a plant with the Krupp-Grusonwerk-Andreas kiln and the Schwenk process edge-mill, showing the arrangement of the plant and how the raw material and fuel are weighed together by an automatic weigher.

INTERNATIONAL DICTIONARY OF CEMENT.

ARRANGED BY DR. C. R. PLATZMANN, WITH COLLABORATORS IN ENGLAND, FRANCE, AND SPAIN.

C

SPANISH.	FRENCH.	ENGLISH.	GERMAN.
costra de sal	croûte salée	efflorescence	Ausblühung
creta	craie	chalk	Kreide
criba giratoria	tamis cylindrique	revolving screen	Trommelsieb
crisol	creuset	crucible	Tiegel
cristal cubreobjetos	couvercle en verre	cover-glass	Deckglas
crudo	poudre crue	raw meal	Rohmehl
cuadrante	cadran	dial	Zifferblatt
cuadro de distribución	tableau de distribution	switchboard	Schalttafel
cubierta o envolvente	tambour	shell	Mantel (Ofen)
cubierta del horno	enveloppe du four	kiln shell	Ofenmantel
cubo	cube	cube	Würfel
cuchara	benne	grab	Greifer
cuerda	élingue	sling	Schlinge

Ch

SPANISH.	FRENCH.	ENGLISH.	GERMAN.
chaveta	goujon ; tourillon	gudgeon	Zapfen ; Bolzen
chimenea	cheminée	chimney	Schornstein

D

SPANISH.	FRENCH.	ENGLISH.	GERMAN.
definición	définition	definition	Begriffserklärung
deformación	déformation	deformation	Formänderung
densidad	densité	density	Dichte
densidad aparente	densité apparente	gravity of volume	Raumgewicht
depósito de corrección de la mezcla	bassin pour la mise au point de la composition	correction tank	Korrektionstank
descarga de cadena	vidange au moyen d'un système à chaîne	chain discharge	Kettenentleerung
descomposición	décomposition	decomposition	Zersetzung
desecho, pérdida	déchet (á l'ensachage)	spillage	Abfall
desembrague	débrayage	disengagement	Ausschaltung
desgaste	usure	wear	Abnutzung
deshidratación	déshydratation	dehydration	Wasserabspaltung, Entwässerung
desintegrar	désagréger	disintegrate, to	zerrieseln
desmenuzarse	tomber en fragments	crumble, to	zerbröckeln
desmoldear	démouler	withdraw from the mould, to	entformen
despacho de mercancías	expédition	dispatch	Verladung ; Verladen, das
deterioro por desgaste	détérioration	wear and tear	Verschleiss
diámetro	diamètre	diameter	Durchmesser
dínamo	dynamo	dynamo	Dynamo
disolvente	solvant	solvent	Lösungsmittel
dispositivo amasador	dispositif d'agitation	stirring gear	Rührgetriebe
distorsión	distortion	distortion	Verkrümmung
draga de cable	excavateur á câbles	dragline excavator	Bagger mit Leitseil, Schrapper
duración de 28 días	durée de 28 jours	twenty-eight days duration	Zeitraum von 28 Tagen
dureza Brinell	dureté Brinell	Brinell hardness	Brinellhärte
durmiente o traviesa	anneau mortier	sleeper	Schwelle

(*Continued on page* 154.)

E

SPANISH.	FRENCH.	ENGLISH.	GERMAN.
eje del piñón	arbre à pignon	pinion shaft	Ritzelwelle
eje hueco	arbre creux	hollow shaft	Hohlwelle
eje que acciona la corona dentada	arbre avec pignon à denture droite	pinion spur wheel shaft	Zahnkranzritzel-welle
electrodo captador	électrode collectrice	collecting electrode	Abscheidungselek-trode
electrodo de descarga	électrode émettrice	discharge electrode	Entladungs-, Ab-scheidungselek-trode
elemento molturador	corps broyeur	grinding medium	Mahlkörper
elevador	appareil de levage	hoisting machinery	Aufzug
elevador volcador	déchargeur-élévateur	hoist tippler	Kippheber
émbolo	piston	piston	Stempel Kolben
émbolo zambullidor	piston plongeur	plunger	Tauchstab, Plunger
embrague	appariel d'embrayage	clutch	Kupplung
embrague magnético	embrayage magné-tique	magnetic clutch	Magnetkupplung
endurecimiento	durcissement	hardening	Erhärtung
energía	énergie	power	Kraft
energía eléctrica	énergie électrique	electric power	elektr. Kraft
enfriador	refroidisseur	cooler	Kühler, Kühlrohr
engranaje cilíndrico recto	{roue d'engrenage ; engrenage droit	spur gear	Stirnradgetriebe
engranaje cónico	engrenage conique	bevel drive	Kegelradantrieb
engranaje de tornillo sin fin	réducteur à vis sans fin	worm gear	Schneckengetriebe
engrasar	lubrifier	lubricate, to	schmieren
ensayar	essayer	test, to	prüfen, untersuchen
ensayo	essai	testing	Prüfung, Versuch
ensayo a la ebu-llición	épreuve d'ébullition	boiling test	Kochprobe
ensayo acelerado de inalterabilidad de volumen	accélérée épreuve de stabilité de volume	accelerated soundness test	beschleunigte Raum-beständigkeitsprü-fung
ensayo al agua fría	essai à l'eau froide	cold water test	Kaltwasserprobe
ensayo de galleta comprimida	épreuve sur galette comprimée et etuvée	compressed-pat kiln test	Presskuchendarr-probe
ensayo de inalterabi-lidad de volumen	épreuve d'invariabilité de volume	soundness test	Raumbeständigkeit-sprüfung
entalladura	denture	tine	Zacke, Zahn
entrehierro	entrefer	air gap	Luftspalt
envasado a mano	mise en sacs à la main	hand filling	Abfüllen, von Hand
envasadora	embarilleuse	barrel packing machine	Fasspackmaschine
escoria	laitier	slag	Schlacke
escoria de altos hornos	laitier de haut four-neau	blast-furnace slag	Hochofenschlacke
esfuerzo de compre-sión	effort de compression	compressive stress	Druckspannung
esfuerzo de flexión	effort de flexion	bending stress	Biegespannung
espátula	spatule	spatula	Spatel
esquisto	schiste	shale	Schieferton
estabilidad de volu-men	invariabilité, stabilité de volume ;	soundness	Raumbeständigkeit
	constance de volume	volume constancy	
estrella triángulo (tipo de)	type étoile-triangle	star-delta type	Sterndreieckstyp (elektr.)
evaporación	évaporation	evaporation	Verdampfung, Verdunstung
excavadora	excavateur	excavator	Bagger
excavadora o draga de cable	excavateur à câbles	dragline excavator	Bagger mit Leitseil, Schrapper
exceso	excès	{surplus	Ueberschuss
		excess	Ueberschuss

E

SPANISH.	FRENCH.	ENGLISH.	GERMAN.
expansión	expansion	expansion	Treiben, das
explosivo	explosif	explosive	Sprengstoff
extracción	extraction	extraction	Absacken, das Abziehen, das
extraer	faire le vide	exhaust, to	entleeren, ausschöpfen

F

SPANISH.	FRENCH.	ENGLISH.	GERMAN.
fábrica	usine	factory	Fabrik
		works	Werk, Fabrik
fabricación del cemento	fabrication de ciment	cement manufacture	Zementherstellung
factor de potencia	facteur de puissance	power factor	Leistungsfaktor
ferrocarril de vía estrecha	chemin de fer à voie étroite	light railway	Kleinbahn
		narrow-gauge railway	Schmalspurbahn
filtro de discos	filtre à disque	disk filter	Scheibenfilter
fin del fraguado	prise finale	final set	Abbindeende
finura	finesse de mouture	fineness	Mahlfeinheit
flecha	flèche	deflection	Durchbiegung
forro del horno	garnissage du four	kiln lining	Ofenfutter
fractura	cassure	fracture	Bruch
fragilidad	fragilité	brittleness	Brüchigkeit
fraguado	prise	setting	Abbinden, das
fraguado rápido	prise rapide	rapid setting	Schnellbinden, das
fuerza centrífuga	force centrifuge	centrifugal force	Zentrifugalkraft
funcionamiento	entretien	maintenance	Unterhaltung, Wartung

(*Continued on page* 156.)

F

SPANISH.	FRENCH.	ENGLISH.	GERMAN.
fundente	fondant	flux	Flussmittel
fundición	fonderie	foundry	Giesserei
fundición de hierro	fonte	cast iron	Gusseisen
fusión	fusion	fusion	Schmelzen, das
fusión incipiente	commencement de fusion	incipient fusion	Sinterung

G

galleta de cemento	galette de ciment	pat of cement	Zementkuchen
garganta, acanaladura	gorge	groove	Rille, Verengung, Kehle
gas de escape	gaz brûlé	exit gas	Abgas
gas del horno de coke	gaz de fours à coke	coke oven gas	Koksofengas
gel	gel	gel	Gel
grado	degré	degree	Grad
grano mezclado	grosseur de grain	grain size	Korngrösse
grasa	graisse	grease	Fett
gravilla	agrégat	gravel	Kies
grieta	fendillement	crack / craze	Sprung
grieta debida a la contracción	fendillement dû au retrait	crack due to contraction	Schwindriss
grieta debida a la dilatación	fissure due à l'expansion	crack due to expansion	Treibriss
grieta o raja en el borde	fendillement sur le bord	edge crack	Kantenriss
grúa	grue	crane	Kran
grúa de cuchara prensora	grue à benne preneuse	grab-crane	Greiferkran
grúa movil	pont roulant	travelling crane	Laufkran
grueso	grossier	coarse	grob
guijarro, silex	cailloux, silex	flint	Flintstein

(To be continued.)